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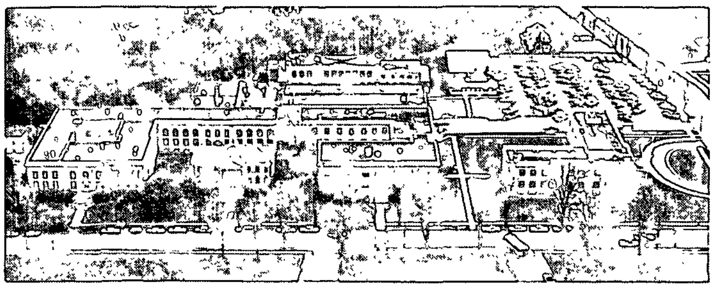

THE INSTITUTE OF PAPER CHEMISTRY, APPLETON, WISCONSIN

OPTIMIZATION OF RECYCLED FIBER IN LINERBOARD

Research Plan
For Continued Work On
2 Project 2697-3 (FKBG)
and Project 2697-53 (IPC)

To The

Fourdrinier Kraft Board Group

of the

American Paper Institute

and

The Institute of Paper Chemistry

March 15, 1977
First Revision August 25, 1978

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PREFACE

The Institute of Paper Chemistry has been requested by the Fourdrinier Kraft Board Group (FKBG) of the American Paper Institue (API) to undertake a research program to maximize the use potentials of recycled fiber in kraft linerboard. The program is directed toward methods which do not adversely affect drainage or strength levels.

Based on meetings with FKBG representatives the Institute submitted a proposal (to conduct a survey to ascertain the technical state of art, an economics study, a raw material availability investigation) and a tentative research outline.

The state of the art survey included consideration of the following:

1. A survey of FKBG members and other companies using recycled fiber in the manufacture of kraft linerboard with regard to amounts employed, processing methods, board quality, and special equipment and problems.
2. European recycled fiber processes.
3. Fractionization techniques, methods, results, and problems.
4. Review of literature.
5. Analysis of process alternatives and revision of tentative research outline.

Based on the survey and conversations with industry personnel the tentative research outline originally submitted was found to be basically sound. However, some specific recommendations for modification of the plan were received and some of these have been incorporated into the revised plan summarized herein.

For example, the original target goal of 25% has been revised upwards since some mills employ blends up to 40% and others use essentially a 100% recycled fiber furnish.

This project is being jointly funded by the Institute and FKBG. Research of a more fundamental nature is funded by the Institute, while the more applied portions are funded by FKBG. In this edition of the plan, specific portions of the work to be supported by Institute funding are outlined in Part V. The cost and time schedules in Part IX have been revised to reflect the funding division between the IPC and FKBG portions of the plan. The revised cost and time schedules also reflect the current lower rate of expenditures by FKBG and IPC projected into the future.

OBJECTIVE

The objective of this program is to maximize the potentials of recycled fiber in kraft linerboard furnish.

I. INTRODUCTION

A. Background

In general the use of recycled fibers in kraft linerboard requires consideration of many technical factors. These mainly involve (a) the removal or dispersion of contaminants in the furnish and (b) the proper processing of the fiber to obtain satisfactory quality levels. This study is directed toward the latter problem.

It is known that recycled fibers differ significantly from virgin fibers (and papers made therefrom) in many of their properties. Recycled fibers refined to the same freeness exhibit lower fiber strength and bonding potentials than the same fiber in the virgin state. The loss in bonding potentials appears to be most critical. In general the properties of the paper which are mainly dependent on fiber bonding and strength decrease markedly with the number of times the fiber is recycled. Furthermore when the recycling is carried out at a given strength level — e.g., bursting strength — it has been noted that it is necessary to refine to progressively lower freeness in successive recyclings. Thus, on successive recyclings the freeness, fiber length and associated sheet properties decrease and can reach impractical levels in terms of production rates and sheet performance. One of the primary differences between virgin and recycled fiber is related to the fact that the recycled fibers do not swell readily in water and, hence, do not bond as well. These differences in bonding potential can be overcome at least in part by additional refining, by the use of chemical swelling and bonding agents, and by increased wet pressing.

The softwood kraft fibers in recycled corrugated material have a greater strength potential in linerboard than do the hardwood semichemical fibers. The latter are usually shorter in length and have a higher lignin and hemicellulose content than the softwood fibers. The semichemical hardwood pulps do not swell as readily in water on repulping. As a result, fractionation of the recycled corrugated material into long and short fractions may lead to strength improvements because the two fractions could be treated or used separately. Selective treatment of the two fractions would be expected to be more effective than treatments of the fibrous composite.

The above and other considerations guided formulation of this research plan and they provided the necessary background for conducting the survey of the technological state of the art with respect to present usage of recycled fiber in kraft liner.

B. State of Art Survey

General

Twelve plant visits and twenty-one telephone interviews have been made as of this time. The plant visits included the following:

1. Five mills which produce linerboard with percentages of recycled fiber ranging from about 8-40% depending on the grade weight and company policy. In four of the five cases the recycled fiber is added to the primary stock; in the fifth case the recycled fiber is added to both the primary and secondary furnishes.

2. Four mills which produce linerboard from 100% recycled fiber. One of the four mills utilizes a Manchester former rather than a fourdrinier machine.

3. One mill which produces recycled fiber medium only but which plans to produce 100% recycled fiber linerboard in the future.

4. One supplier of recycled fiber and one research facility.

The research program as originally outlined was generally endorsed as a result of these visits. Specific recommendations for modification of the research plan were received and some of these have been incorporated into the research plan.

In this connection the original plan called for the target use of 25% recycled fiber. However, this target has been increased since up to 40% recycled fiber is now being used in 42 lb linerboard running at 1400 fpm and 100% recycled fiber is employed at slower speeds. Some comments indicated that the break point on strength occurred at from 20 to 30%.

Refining

Presently most mills blending virgin and recycled fiber stocks are refining the stocks together using disc refiners. There was general agreement that a study of refining should be part of the final research plan. A number of the mills were considering separate refining of the virgin and recycled fiber stocks and hence felt that separate refining should be a part of this program.

Chemical Additives — Bonding, Drainage & Swelling Agents

One of the primary differences between virgin and recycled fibers is that recycled fibers do not swell readily in water and hence do not bond as well in the papermaking operation. To an extent the deficiency in bonding can be overcome by additional refining or by the use of chemical additives such as swelling agents or bonding agents. Some practical swelling agents are alkaline materials and higher strength values are usually obtained when recycled fibers are treated with such swelling agents. The use of alkaline swelling agents would also necessitate use of alkaline sizing agents.

Chemical bonding agents offer the possibility of obtaining the desired strength by combinations of additives and limited refining.

In general, the survey being currently conducted has indicated that the use of additives deserves an important place in the study. The users of high percentages of recycled fiber find them essential in maintaining strength. Starches and gums are presently used for this purpose — both as beater additives and on the size press.

None of the companies visited are using swelling agents at present but their inclusion in the study was generally favored. One company cautioned against the use of caustic soda because they believe it will aggravate the problem of sticky deposits.

Fractionization

This portion of the proposed study was believed to be important by a number of the companies surveyed. Several methods of accomplishing the fractionization have been reviewed but the only working commercial system surveyed was based on the Cellusizer made by Black Clawson. This is a barrier screen in which the "rejects" become the long fraction and the "accepts" the short fraction. For this part of the study it is planned to arrange with Black Clawson to fractionate a suitable quantity of recycled fiber and carry out the remainder of the laboratory work at the Institute as outlined in the program.

When a mill is running both liner and medium the short fraction can be used in the medium. Another possibility is to include the short fiber in the top furnish for better printability and possibly better appearance. In this respect it may be noted that "dirt" tends to be absorbed preferentially by the fines and therefore may adversely affect printability and appearance.

Asphalt Dispersion

There appears to be considerable controversy relative to the necessity for asphalt dispersion (A-D) equipment in the recycled fiber processing system. Some companies believe the A-D units are necessary while others believe that proper screening will remove all the objectionable contaminants. The possible adverse effects of A-D treatment on bursting strength have been cited as another objection to its use. On the other hand, such systems provide conditions of relatively high temperature and pressure as well as reaction time. Thus, it is possible that the addition of chemical agents in the dispersion system may be one way to improve quality. Experiments to evaluate the impact of A-D units are included in this research plan.

Machine Trials

The evaluation of the effects of different approaches on the sheet strength development by means of handsheets permits the most economical and practical examination of a wide range of variables and degrees of treatment. However, such studies have definite limitations as to the scope of the information which can be developed and the degree to which it can be translated to mill scale processing without modification. For example, handsheets provide little information as to runnability on the paper machine — i.e., operational problems, speed limitation, forming, pressing and drying characteristics, etc.

Translation of the laboratory results to mill scale trials should be carried out by a two-step program involving first pilot scale trials and secondly, mill scale trials. The pilot scale trials will involve stock preparation and subsequent manufacture of "duplex" linerboard on a narrow width machine. They will provide a means for making a preliminary evaluation of the various candidate approaches as well as to work out problems before proceeding with the full scale machine trials. Both pilot and full scale machine trials are included in the plan.

Impact of Contaminants

The program as planned deals with board strength and proposes no assessment of the problems associated with contaminant removal. It is recognized, however, that contaminant removal is one of the most important problems associated with the use of post consumer boxes.

The recent publication "Paper Recycling — The Impact of Contaminants 1973-1985" comments on the problem as follows: "Moreover, present in-mill cleaning technology is designed for the concentration and characteristics of pre-1973 waste paper. Clean post consumer waste paper will become more scarce as recycling rates rise. Thus, there is a requirement for more sophisticated in-mill pulp cleaning technology to be combined with an intensive effort on the part of the industry to control the nature and amounts of potential contaminants which are applied to corrugated containers and newspapers."

Contaminants affect the production of linerboard in many ways. They adversely affect the appearance of the sheet and cause difficulty in the forming, pressing, and drying due to plugged wires and felts, and "coated" press rolls and drier drums. In addition, they may have an adverse effect on the quality of the linerboard in terms of lower strength.

Research Outline

An outline of the proposed research program is shown below and the detailed research plan is presented in the following sections of this document. (Note: The subjects are listed so as to correspond with subsequent sections of this plan.)

II. Objective

III. Investigation of addition of composite recycled fiber from old corrugated containers (OCC)

- A. Background
- B. Fibrous raw material
- C. Study of use of composite recycled fiber in kraft linerboard
  1. Control sample analysis — establishment of base line
     - a. Virgin pulp
     - b. Composite recycled fiber from OCC
     - c. Blends of virgin pulp and composite OCC fiber

d. Analysis of control sample base-line results

2. Optimization of composite OCC fiber in primary and secondary furnishes

a. Distribution of OCC fiber in primary and secondary furnishes

1) Proposed distribution ratios

2) Evaluation of stocks and handsheets

3) Analysis of results

b. Effect of increasing percentage of OCC fiber on kraft linerboard quality

1) Proposed percentages

2) Evaluation of stocks and handsheets

3) Analysis of results

D. Study of refining techniques

1. Background

2. Variables to be investigated

3. Evaluation of stocks and handsheets

4. Analysis of results

E. Development of most appropriate technique for refining virgin pulp and composite OCC fiber

1. Refining of mixtures of virgin and OCC fiber

2. Separate refining

3. Analysis and selection of most appropriate refining technique

F. Strength development via chemical additives

1. Background

2. Investigation of swelling agents

a. Effect of pH on virgin pulp strength

b. Effect of swelling agents on composite OCC fiber

1) Swelling agents

2) Evaluation of stock and handsheets

3) Analysis of results

3. Investigation of alkaline size

a. Virgin pulp

b. Recycled fiber

4. Application of bonding agents

G. Effect of wet pressing on strength development

H. Analysis of overall results

IV. Investigation of fractionized OCC recycled fiber

A. Fractionization of OCC fiber

B. Long fiber fraction

1. Development of base-line control sample analysis

a. Strength development of long fiber fraction

b. Blends of virgin pulp and long fiber fraction

c. Evaluation of stocks and handsheets

d. Analysis of results

2. Optimization of long fiber fraction distribution in primary and secondary furnishes

a. Distribution of long fiber fraction

1) Distribution ratios

2) Refining conditions

3) Evaluation of stocks and handsheets

4) Analysis of results

b. Effect of increasing percentages of long fiber fraction on linerboard quality

3. Investigation of refining of long fiber fraction

4. Development of most appropriate technique for refining virgin pulp and long fiber fraction

5. Study of chemical additives

a. Swelling and delignification treatments

b. Investigation of bonding agents

C. Short fiber fraction

1. Background

2. Investigation of the effect of removing fines from the short fiber fraction

3. Development of short fiber fraction base-line data

4. Optimization of distribution of short fiber fraction in primary and secondary furnishes

5. Effect of refining on short fiber fraction

6. Study of chemical treatments

a. Swelling and delignification treatments

b. Investigation of bonding agents

7. Effect of wet pressing on strength development

V. Funded Pulp Treatment Studies

A. Funded study of ozone treatments

1. Legal and patents

2. Process research

3. Optimization of ozonated and untreated fiber combinations

4. Pilot scale process trials

5. Process alternatives and cost

B. Funded study of fiber treatments

1. Study of alternative chemical treatments

2. Optimized use of chemical additives

3. Study of refining techniques

4. Wet pressing

5. Fiber fractionation

VI. Investigation of the effect of asphalt dispersion process on fiber and sheet properties

A. Background

B. Effect of Asplund conditions on strength and drainage of composite OCC fiber

C. Effect of Asplund conditions on strength and drainage on long fiber fraction

D. Effect of Asplund conditions on strength and drainage of short fiber fraction

VII. Selection of candidate approaches

VIII. Machine trials

II. OBJECTIVE

To conduct a comprehensive research program maximizing the use of OCC recycled fiber in the manufacture of linerboard. This would result in techniques which do not adversely affect either strength or drainage. It is stipulated that the treatments to be investigated will not be limited to the fibers from OCC as it may be advantageous to change the characteristics of the virgin pulp fibers to obtain a more efficient interaction with the fibers from OCC in so far as production and quality are concerned.

III. INVESTIGATION OF ADDITIONS OF COMPOSITE RECYCLED FIBER FROM OLD CORRUGATED CONTAINERS (OCC)

A. Background

The work in this phase consists, in its simplest sense, in a two-fiber factor relationship directed to the most practical and economical manufacture of kraft linerboard. These two factors are: (1) virgin kraft pulp fibers, and (2) fibers from OCC. The form of the virgin fibers is established as slush pulp fibers. The form in which to add the OCC fibers is as the natural composite. Although the ratio of the softwood kraft fiber to the hardwood semichemical fiber varies with the combined board material combination, it is generally considered that the ratio of linerboard to medium is approximately 2:1.

Softwood kraft and semichemical hardwood pulps differ in that the softwood kraft fibers have greater strength potential in linerboard than do the unbleached semichemical fibers. The latter are usually pulped to approximately 80% yield and thus undergo little delignification which makes it difficult to develop fiber bonding. Although the semichemical hardwood pulps have a higher hemicellulose content than softwood kraft fiber, the hemicellulose apparently are not available in a "form" which readily promotes swelling in water. This inability to swell in water apparently detracts from strength regeneration. Also the softwood kraft fibers have a substantially longer average fiber length than do the hardwood semichemical fibers.

These differences suggest that another form in which to consider strength improvement of such widely divergent fibers is as different fiber fractions — e.g., (1) long fiber fraction containing primarily the linerboard fibers, and (2) short fiber fraction primarily representative of the corrugating medium. Although fractionation involves another processing step in stock preparation, it does offer the opportunity to administer treatments which are specific relative to the fibrous materials in question. Because of this, these selected treatments would be expected to achieve a greater degree of effectiveness than when applied to a heterogenous fibrous composite.

B. Fibrous Raw Materials

It is proposed that the OCC furnish be obtained in the form of 200-lb series combined board made from 42-lb unbleached kraft linerboard and 26-lb semichemical corrugating medium. This will provide a convenient and reliable way of making sure that the OCC fiber is of constant quality. Further, this method will provide the least interference from contaminants as well as make it easier to fractionate in subsequent phases of this study.

It is also proposed to use slush virgin pulp. A quantity of such pulp will be procured. This procedure will provide a plentiful supply of uniform pulp and OCC fiber with which to work.

C. Study of Use of Composite Recycled Fiber (OCC) in Linerboard

OCC as used herein refers to the "standard" 200-lb series combined board obtained for the study. It is proposed to carry out the initial phase of the study with this general form of OCC material because it is the simplest and most economical way of procuring and processing as a supplementary fiber source.

It is proposed that control samples be employed to serve as reference against which to measure progress. The control sample analysis will involve determining the strength potentials of handsheets as well as selected parameters of the stock such as freeness, fiber length distribution and drainage. It is proposed that duplex handsheets — i.e., primary and secondary plies — be made using a special sheet former, designed to produce a duplex sheet — e.g., Beloit double headbox-type sheet mold.

1. Control Sample Analysis — Establishment of Base Lines

The purpose of the control sample analysis is twofold: 1) to characterize each fiber source and 2) to provide reference data as a basis for determining the most likely candidate approaches leading to the optimization of the use of OCC in the manufacture of linerboard.

a. Virgin Pulp

(1) Mill Refined Primary and Secondary Furnishes

A quantity of mill refined primary and secondary pulps, sampled after refining but prior to the addition of white water, will be obtained together with detailed information regarding the refining conditions, etc. The mill refined stocks will be evaluated for pH, freeness, fiber length distribution and drainage. The mill refined stocks are to be made into duplex handsheets using the specified ratios of primary and secondary furnishes used by the mill in the production of 42-lb kraft linerboard. The duplex handsheets will be evaluated for such properties as basis weight, caliper, bursting strength, tensile strength, stretch, edgewise compression, extensional stiffness, etc.

(2) Virgin Slush Pulp(s)

The virgin slush pulp(s) taken before mill refining (if primary and secondary pulps are different, each will be used and combined in proper proportions in final sheet) will be refined in The Institute of Paper Chemistry's laboratory disc refiner to the same freeness levels as were used in the mill refining and made into duplex handsheets. The resulting stocks and handsheets will be evaluated in terms of the previously suggested stock characteristics and handsheet properties.

(3) Determination of Appropriate Laboratory Refining Procedures

The results obtained on the virgin slush pulps above will be compared with the results obtained on the mill refined stocks and handsheets, and the refining procedure on the slush pulps varied to provide stock and handsheet properties reasonably close to those obtained with the mill refined stock. The refining procedure adopted will be henceforth referred to as the Control Sample Refining Conditions.

b. Composite Recycled Fiber from OCC

The initial strength potentials of the composite OCC fiber will be determined by refining the composite OCC fiber using the Control Sample Refining Conditions and removing samples for evaluation at various intervals of refining. The interval samples will be evaluated for stock characteristics and also made into handsheets for the subsequent determination of sheet properties.

The data will provide information as to the degree of refining required to develop maximum bursting strength by the refining conditions used.

c. Blends of Virgin Pulp and Composite OCC Fiber

The work in this area will be carried out using a 70:30 (by weight) ratio of primary to secondary stocks and a virgin pulp:composite corrugated waste ratio of 70:30. Subsequent phases of the study will consider blends up to 50:50 as well as 100% recycled fiber furnishes. The Control Sample Refining Conditions are to be used.

(1) Blend of Virgin Pulp and Composite OCC Fiber — Refined as a Mixture

Combine virgin pulp with composite OCC fiber in the desired proportions. Separate into primary and secondary portions. [NOTE: this anticipates that primary and secondary pulps are the same and the stocks vary only in the degree of refining. If this is not the case the appropriate changes will be made.]

Refine each portion in the Institute's laboratory refiner using the Control Sample Refining Conditions and end point. Handsheets will be made and evaluated as in Part C-1-a.

(2) Blend of Virgin Pulp and Composite OCC Fiber — Refined Separately

Repeat (1) above but refine virgin pulp and composite OCC fiber separately to the same level as the blend used in (1) above, then combine to form primary stock. Follow the same basic procedure for the secondary stock. Make duplex sheets and evaluate stock and handstock characteristics as in Part C-1-a.

(3) Blend of Virgin Pulp and Composite OCC Fiber — Refined to Maximum Bursting Strength Level

Repeat (2) above except refine the composite OCC fiber to the level of maximum bursting strength as determined in C-1-b prior to blending with primary and secondary furnishes. Then determine the characteristics of the blends of primary and secondary furnishes as well as the physical properties of the duplex handsheets.

d. Analysis of Control Sample Base-line Results

Analysis of the results obtained on the control samples will indicate the direction of future work. For example, if separate refining indicates significant improvement, then it would be logical to consider this in carrying out subsequent phases of the study. Theory and practice anticipate that separate refining will be advantageous especially in those situations where substantial quantities of composite fiber are used. When virgin fibers and recycled fibers are refined together it is believed that the recycled fiber undergo little actual change because of their greater resistance to refining as a result of their exposure to at least one papermaking cycle. Similarly, refining the composite OCC to the level of maximum bursting strength may show a significant improvement in strength but be accompanied by a prohibitive loss in drainage. If this should be found then consideration should be given to the use of refining in combination with drainage aids, etc.

2. Optimization of Composite OCC Recycled Fiber Distribution in Primary and Secondary Furnishes

Because of the numerous possible blend ratios it is impractical at this time to explore all possible blends. Rather it is intended to investigate a limited number of blend ratios within the two furnishes based on overall target ratios of virgin pulp to composite OCC fiber of 70:30, 60:40, and 50:50. The most appropriate refining procedure determined in Part C-1 will be employed.

a. Distribution of Secondary Fiber in Primary and Secondary Furnishes

(1) Proposed Distribution Ratios

The proposed distributions of composite OCC waste in the primary and secondary furnishes are tabulated in Table I for three blends of virgin and recycled fiber.

TABLE I

DISTRIBUTION OF FIBERS

Type of Fiber, %			
Primary 70% of Board		Secondary 30% of Board	
Virgin Pulp, %[a]	Recycled OCC, %[a]	Virgin Pulp, %[a]	Recycled OCC, %[a]
Blend: 70% Pulp/30% Recycled			
40	30	30	0
45	25	25	5
49	21	21	9
55	15	15	15
60	10	10	20
65	5	5	25
Blend: 60% Pulp/40% Recycled			
30	40	30	0
40	30	20	10
50	20	10	20
60	10	0	30
Blend: 50% Pulp/50% Recycled			
20	50	30	0
25	45	25	5
35	35	15	15
50	20	0	30

[a]Percent of total linerboard weight.

(2) Evaluation: The stocks and handsheets will be evaluated for the appropriate properties as listed in Part C-1, page 15.

(3) Analysis of Results

The analysis of the data should provide insight as to the most efficient distribution of the composite OCC fiber between the primary and secondary stocks and, hence, plies.

b. Effect of Increasing Percentage of OCC Recycled Fiber on Kraft Linerboard Quality

The purpose of the research in this area is to determine the effect of increasing amounts of OCC fiber composite on the quality of kraft linerboard. It is proposed to use the most appropriate distribution of recycled fiber and refining technique developed in the previous sections of this study. The proposed percentages of composite OCC fiber are set forth below:

(1) Proposed Percentages of Composite OCC Recycled Fiber: 0, 10, 20, 30, 40, 50 and 100

(2) Evaluation: The stocks and handsheets will be evaluated for the appropriate properties as listed in Part C-1, page 15.

(3) Analysis of Results

The results should indicate the maximum percentage of composite corrugated waste which can be used in the manufacture of kraft linerboard and meet the target strength and drainage requirements for the condition used. In addition, the results will indicate which parameters are the limiting factor.

D. Study of Refining

1. Background

The exposure of cellulose papermaking fibers to one or more papermaking cycles introduces changes in the fiber morphology and chemistry which adversely affects the inherent fiber strength as well as its ability to swell and fibrillate in water. This results in a loss in fiber bonding unless the fiber is subjected to additional refining, or bonding agents are used.

In most linerboard mills currently using supplementary recycled fiber, the virgin fiber is blended with the recycled fiber prior to refining. Further it is known that recycled fiber is less responsive to the action of the refiners than the virgin fibers. When virgin and recycled fibers are refined together the recycled fibers are probably refined very little and thus act primarily as a fiber filler. Further it has been demonstrated that when virgin and recycled fibers are refined to the same level (same freeness) the virgin fiber will yield a stronger sheet due primarily to better bonding. Equivalent strength levels can be achieved with the recycled fibers, however they must be refined more to develop equivalent bonding.

It would be expected that the refining technique would have an important effect on the strength development of the composite OCC fiber. Accordingly, it is proposed to study the effect of refining variables on the strength development of composite OCC using disc refiners such as a 36-inch Bauer double disc refiner equipped with an assortment of plates.

2. Variables to be Investigated: The variables listed below are expected to affect the degree of cutting, fibrillation, swelling, drainage resistance and power consumption.

   a. Type tackle or plate design (selected designs may result in less cutting, better fibrillation, lower power, etc.

   b. Setting — power consumption

   c. Feed rate

   d. Consistency (less cutting may be obtained at higher consistencies)

   e. Temperature (generally, higher temperatures are expected to adversely affect swelling)

3. Evaluation: The stocks and handsheets will be evaluated for the properties listed in Part C-1, page 15.

4. Analysis of Results

The information generated in this area will indicate the degree and most appropriate conditions of refining for the optimum development of strength oc composite OCC fiber designed for use in linerboard.

E. Development of Most Appropriate Technique for Refining Virgin Pulp and Composite Recycled Fiber

The information developed above for composite OCC recycled fiber will be utilized in developing the most effective technique for refining linerboard furnish:

1. Refining of Mixtures of Virgin Pulp and Composite OCC

2. Separate Refining of Two Component Primary and Secondary Furnishes

3. Analysis and Selection of Most Appropriate Refining Technique

F. Strength Development via Chemical Additives

1. Background

A number of studies have been carried out which have indicated that the primary difference between virgin and recycled kraft softwood fibers is the inability of the latter to swell readily in water and hence develop bonding. The deficiency in bonding can be overcome by additional refining or by the use of chemical additives such as swelling agents or chemical bonding agents. The practical swelling agents are usually alkaline materials — i.e., caustic soda or amines. In addition, it is common practice in some mills to increase wet pressing up to 1000 pounds per lineal inch of width to improve bonding.

2. Investigation of Swelling Agents

It is generally found that higher bursting strength is obtained when the stock is at a pH of from 9.0 to 9.5. Further, when OCC is treated with swelling agents such as caustic soda to give a pH in the above range, higher strength levels are obtained. Accordingly, it is proposed to investigate the effect of practical swelling agents on the strength development of composite OCC as well as maintain the virgin pulp on the mild alkaline side. This latter will necessitate the use of an alkaline size.

a. Effect of pH on Virgin Pulp Strength

The pH of the virgin pulp will be adjusted by means of caustic soda or hydrochloric acid.

(1) Preparation of Virgin Pulp Handsheets at pH of 10.0

(2) Same as (1) Above Except pH = 9.0

(3) Same as (1) Above Except pH = 6.5

(4) Same as (1) Above Except pH = 5.3

b. Effect of Swelling Agents on Composite OCC Recycled Fiber

Swelling agents should be mixed with the composite OCC as follows:

(1) Swelling Agents — pH levels of 8.0, 9.0 and 10.0

Soda ash (if successful may be possible to use green liquor)

Caustic soda (if successful may be possible to use white liquor)

Sodium silicate (inexpensive swelling agent)

Combination of above (combinations may result in better strength/cost ratio)

Amines — primary, secondary, tertiary, and quaternary (compounds of this type are effective swelling agents)

(2) Evaluation of Stock and Handsheets

The stocks prepared at the pH levels indicated in a. and b. above should be refined (standardized) and made into handsheets at the pH level of the stocks. The characteristics of the stock and handsheets are to be determined as in Part C-1, page 15.

(3) Analysis of Results

The results obtained in this section will provide information as to the degree to which alkaline swelling agents are effective in developing the strength of composite OCC fiber.

3. Investigation of Alkaline Size

If swelling agents, investigated in F-2 above, are found to be beneficial in developing strength, their use will necessitate the use of alkaline size such as Aquapel made by Hercules. Although Aquapel is much higher in cost on a per pound basis than conventional size, its efficiency is considerably greater and thus the use of an alkaline size may be practical economically. Accordingly, the various alkaline sizes will be investigated in terms of effectiveness and cost.

4. Application of Bonding Agents

The objective of this section is to determine the degree to which bonding agents may be used to optimize the strength of composite OCC recycled fiber. Bonding agents offer the possibility of obtaining the desired strength by a combination of a) bonding agent plus limited refining, or b) bonding agent plus drainage aid and limited refining. In addition, many bonding agents may be added at the size press which has many advantages such as complete retention, less pollution, etc. The applications of bonding agents — beater or size press — frequently permit attainment of the desired strength level with less adverse effect on drainage than would result if the strength were obtained solely by refining.

Bonding agents which have the capacity to enhance fiber-fiber bonding consist of two classes: a) natural and b) synthetic bonding materials. The natural bonding agents include such materials as starch (anionic and cationic) and natural gums (locust bean gum, guar, etc.). Locust bean gum and guar are natural occurring mannogalactan products. Such materials are effective bonding agents over a wide range of pH. The synthetics include wet strength resins — e.g., urea formaldehyde, melamine, polyamine-polyamide-epichlorohydrin (Kymene 557), etc., and polyacrylamides (Acco-strength). The urea and melamine formaldehyde resins are wet strength agents which are effective under acidic conditions. They are also capable of improving dry strength.

Kymene is a wet strength and bonding agent which is effective in the 6-8 pH. range. The polyacrylamide types can function either as a bonding agent or retention aid depending on molecular weight. The efficiency of bonding agents vary with the type of fiber as well as the environmental system in which they are used. In general, softwood fibers are relatively responsive to chemical bonding agents. In contrast, there are very few materials which are effective as bonding agents when applied to high-yield unbleached hardwood semichemical fibers.

The Institute is conducting a funded research program directed to improved bonding of semichemical pulps. The strength of high-yield pulps appears to be low because lignin restricts swelling and provides greater fiber stiffness, which encourages weak interfiber bonding. If the ligneous fibers can be made to take up more water and swell more uniformly without sacrifice in yield, stronger and more versatile pulps could be produced. Thus we are attempting to determine the effects of mild physical chemical treatments on the swelling and stiffness of high-yield pulp fibers, and to determine the effects of the more promising treatments on the strength properties of the pulp.

The types of treatment under consideration in the Institute funded study include: (1) microwave radiation, (2) ozone, (3) nitrogen dioxide, (4) corona discharge, (5) plasticizers, (6) swelling agents, and (7) chemical treatments which may be suggested by results obtained in the pulping projects under way at the Institute. Application of this research will be pursued in this study for those types of treatment which appear promising.

For the study outlined herein, the investigative program will evaluate the strength development and drainage characteristics of composite OCC recycled fiber as follows:

a. Refining only
b. Refining and size press application of selected bonding materials, with and without beater addition
c. Combination of "beater" added bonding agent and limited refining
d. Combination of bonding agent, drainage aid, and limited refining

G. Effect of Wet Pressing on Strength Development

The primary difference between virgin and recycled fiber is lower bonding which manifests itself in lower strength properties such as tensile strength, etc. As mentioned in a previous section some linerboard mills using a furnish consisting of part or 100% composite OCC recycled fiber have found that better bonding and hence better bursting strength is obtained by using high wet pressing. Accordingly, it is proposed to investigate the effect of wet pressing on tensile and compressive strength characteristics of virgin pulp and composite OCC recycled fiber.

H. Analysis of Overall Results

Analysis of the results obtained in this part of the study should indicate the maximum amount of composite OCC recycled fiber which can be used in linerboard furnish, the most appropriate distribution between primary and secondary stock and the optimum conditions for developing the strength of the recycled fiber portion.

IV. INVESTIGATION OF FRACTIONIZED OCC RECYCLED FIBER

OCC is composed of two primary fibrous components — kraft linerboard and corrugating medium — which can be separated in the wet by suitable screens into long and short fractions. On the average, these fractions are in the ratio of 2:1 liner fiber:medium fiber. These two fractions differ strikingly in terms of fiber composition. If the "cut" is made properly the long fraction will contain mainly unbleached softwood kraft fibers which have reasonably good strength regenerative potentials. In contrast, the short fraction will consist mainly of unbleached high-yield hardwood semichemical fibers which even as virgin fibers would not produce as high a strength sheet as linerboard. Further, their strength potentials decrease markedly once they have been exposed to one or more papermaking cycle.

It is to be expected that because of differences in fiber specie, degree of delignification, etc., the two fractions will react differently to various mechanical and/or chemical treatments. Therefore, fractionization provides the opportunity to treat each fraction differently. Fractionization of recycled fiber from OCC is not considered to be an impossible problem today although it does require an additional step in the processing. Further, both fractions must be used to make the process most economically attractive. In those cases where a linerboard mill has the good fortune to be located on the <u>same site</u> as a corrugating mill, the short fraction can be used in the medium furnish. However, if no such outlet exists, it is necessary for the short fraction to be used in some way otherwise the fiber loss is prohibitive. The research plan considers its possible use in both primary and secondary furnishes.

It is the objective of the research in this phase to determine how best to treat each fraction so as to optimize the contribution of the respective fractions in the manufacture of kraft linerboard with a furnish of virgin pulp and OCC. To this end it will be necessary to fractionate the corrugated waste, however, this should be a relatively straightforward procedure by means of the appropriate screen — e.g., Black-Clawson Cellusizer.

A. Fractionization of OCC Fiber

The 200-lb series combined board should be "defibered" in water at relatively low consistency and then run over the appropriate fractionating equipment. Several different fractionization ratios will be evaluated to determine the most appropriate ratio.

B. Long Fiber Fraction

1. Development of Base Line Control Sample Analysis

The same general approach will be used in establishing a base line for the long fiber fraction as was used for the composite OCC fiber (see Section III-C-1, pages 15-19).

a. Strength Development of Long Fiber Fraction

The long fiber fraction will be refined using the control sample refining conditions except that stock samples will be removed at various refining intervals for evaluation of stock characteristics and handsheet properties as in Part III-C-1b, page 16.

b. Blends of Virgin Pulp and Long Fiber Fraction

It is assumed that even though the OCC fiber is fractionated, both fractions will need to be used for economic reasons although the treatment given each fraction may differ.

For ease of comparing the effect of the different fractions of the OCC fiber it is proposed that in the investigation of fractionated OCC fiber that the virgin pulp content of the linerboard furnish be standardized at 70%. Thus in the case of the long fiber fraction the content of the latter will be 30% rather than the 20% which it would be if both fractions of a 30% total OCC were used. Higher percentages of long fiber will be studied in a later section.

(1) Refine Blend of Virgin Pulp and Long Fiber Fraction

Primary and secondary stock will be prepared using the respective control sample refining conditions in Section III-C-1(a), page 16.

(2) Same as (1) above except refine each stock constituent separately and then combine to form primary and secondary stocks.

(3) Same as (1) above except refine long fiber fraction to its maximum bursting strength.

c. Evaluation: The stocks and handsheets will be evaluated for the properties noted in Part III-C-1, page 15.

d. Analysis of Results

Analysis of the results obtained above should indicate the degree to which the long fiber fraction contributes to linerboard quality under different conditions of processing.

Also, the analysis should indicate the maximum degree to which the long fiber fraction can be expected to contribute to linerboard quality via refining only. These data should be useful as a basis for judging the direction in which to move.

2. Optimization of Long Fiber Fraction Distribution in Primary and Secondary Furnishes

   a. Distribution of Long Fiber Fraction

      (1) Distribution Ratios

      The suggested ratios are tabulated in Table II.

      (2) Refining Conditions

      It is suggested that the most effective refining technique determined in III-C-1, page 15 be used.

      (3) Evaluation: The stocks and handsheets will be evaluated for the properties listed in Part III-C-1, page 15 as are appropriate.

      (4) Analysis of Results

      The analysis of the results obtained above should provide insight as to the most effective distribution of the long fiber fraction between primary and secondary furnishes for the degree of refining and proportions of long fiber fraction used. It may be that when the short fiber fraction is included with or without treatment, the optimum distribution may shift.

TABLE II

DISTRIBUTION OF FIBERS

Type of Fiber, %			
Primary 70% of Board		Secondary 30% of Board	
Virgin Pulp, %[a]	Long Fraction, %[a]	Virgin Pulp, %[a]	Long Fraction, %[a]
	70% Pulp: 30% Long Fraction		
40	30	30	0
45	25	25	5
49	21	21	9
55	15	15	15
60	10	10	20
65	5	5	25
	60% Pulp: 40% Long Fraction		
30	40	30	0
40	30	20	10
50	20	10	20
60	10	0	30
	50% Pulp: 50% Long Fraction		
20	50	30	0
25	45	25	5
35	35	15	15
50	20	0	30

[a]Percent of total linerboard.

b. Effect of Increasing Percentages of Long Fiber Fraction on Linerboard Quality

It is proposed that the optimum conditions determined above be utilized in determining the effect of adding increasing amounts of long fiber fraction up to a maximum of 67% of total furnish which is the long fiber fraction equivalent of 100% OCC recycled fiber furnish.

(1) Proposed Percentages of Long Fiber Fraction:

6.7% (10% total OCC equivalent)
13.3% (20% total OCC equivalent)
20.0% (30% total OCC equivalent)
26.7% (40% total OCC equivalent)
33.3% (50% total OCC equivalent)
66.7% (100% total OCC equivalent)

(2) Evaluation: The stocks and handsheets will be evaluated for the properties listed in Part III-C-1, page 15.

(3) Analysis of Results

The results will indicate the degree to which various amounts of long fractions may be used and still meet the strength and drainage requirements.

3. Investigation of Refining of Long Fiber Fraction

The same general approach as described for the composite OCC recycled fiber is intended for the long fiber fraction. It should be emphasized that the optimum conditions for the long fiber fraction will not necessarily be the same as determined earlier for the composite OCC fiber. The variables to be considered are described in Part III-D, pages 22 and 23.

4. Development of Most Appropriate Technique for Refining Virgin Pulp and Long Fiber Fraction

The information developed above for the long fiber fraction will be utilized in developing the most appropriate technique for refining linerboard furnishes.

a. Refining of Mixtures of Virgin Pulp and Long Fiber Fraction
b. Separate Refining of Two Component (i.e., Virgin and long fiber from OCC) Primary and Secondary Furnishes
c. Analysis and Selection of the Most Appropriate Refining Technique

5. Study of Chemical Additives

It is hypothesized that some physiochemical treatment is needed which is selective to high-yield softwood kraft fibers and which will bring about a mild increase in delignification, swelling and/or fibrillation of the fibers and thus increase their bonding efficiency.

In considering the proposed treatments, it should be emphasized that many supplementary recycled fiber systems contain an Asplund defibrator or equivalent for "de-asphalting" OCC fibers. Such systems provide conditions of relatively high temperature and pressure as well as reaction time. Accordingly, there is the possibility of utilizing these conditions in some of the treatments without requiring additional capital expenditures for such mills.

a. Swelling and Delignification Chemical Treatments

Inasmuch as swelling is exothermic, the treatments directed to mainly swelling should be carried out at normal temperature. When the same chemical materials are used for delignification, heat will be beneficial — e.g., process in Asplund. In addition to the swelling agents listed in Part III-F-2, page 25, the following treatments will be studied.

(1) Hypochlorite Treatment (on acidic and alkaline side)

The underlying concept of the use of hypochlorite above is to subject the long fiber fraction to a relatively mild delignification. It is hoped that if the delignification can be limited to the "surface" of the fibers, new bonding sites will be exposed without significantly decreasing the inherent fiber strength. Oxidation and hence degradation will be more rapid on the acid side thus the exposure time should be shorter which will allow less time for penetration into the fiber. Many of the treatments suggested above could be carried out in the Asplund mill.

Chlorine could be used to do the same as the hypochlorite treatment, however it is estimated that the long fiber fraction will absorb 8-10% chlorine immediately with a corresponding loss in yield.

(2) Oxidation Extraction

This treatment would be carried out in the Asplund mill and would involve adding approximately 3% caustic and 2% hypochlorite as a start.

b. Investigation of Bonding Agents

One of the difficulties encountered when a chemical bonding agent is added to a furnish consisting of long fibers, short fibers, and fines, is selective absorption of the bonding agent by the fines. This condition provides the least efficiency in terms of bonding strength.

Inasmuch as the fines haye been removed from the long fiber fraction via fractionization, it is hoped that increased bonding efficiency can be obtained by the use of bonding agents with the long fiber fraction. Frequently it is possible to achieve the desired strength with less loss in drainage by substituting bonding agents for a portion of the refining.

It is intended to study the relative efficiency of natural and synthetic bonding agents which have the best affinity for unbleached kraft fibers.

(1) Natural Materials

(a) Starch (anionic and cationic)

(b) Gums (mannogalactans, guar, locust bean gum, etc.)

(c) Combination of starch and gum — e.g., starch and guar.

(Previous work suggests that combinations of starch and guar may be more efficient in terms of strength/cost ratio than either by themselves.)

(2) Synthetic. These materials are known bonding agents.

(a) Urea-formaldehyde

(b) Melamine

(c) Polyamine (Kymene 557)

(d) Polyacrylamide (Acco strength)

(3) Investigative Program

The investigative program will evaluate the strength development and drainage characteristics of long fiber fraction of OCC fiber when the strength regeneration is derived by:

(a) Refining only

(b) Refining plus size press application of selected bonding materials, with and without "beater" additives

(c) Combination of bonding agents and limited refining

(d) Combination of bonding agent, drainage aid and limited refining

6. Study of the Effect of Wet Pressing on Strength Development

Some linerboard mills using large percentages of OCC have found that better bonding and hence better strengths are obtained by using higher than normal levels of wet pressing. Accordingly, it is proposed to investigate the effect of wet pressing on the strength of the long fiber fraction.

7. Analysis of Overall Results on Long Fiber Fraction

Analysis of the results obtained in this section should indicate the maximum amount of long fiber fraction which can be used in linerboard furnish, the most appropriate distribution between primary and secondary stock and the optimum conditions for developing the strength of the long fiber fraction.

C. Short Fiber Fraction

1. Background

As pointed out earlier, OCC is essentially composed of two primary fibrous components — i.e., kraft linerboard and corrugating medium. On the average the linerboard and corrugating medium fiber are present in corrugated board in the ratio of 2:1 liner-medium. These two components are markedly different in terms of fiber composition. The linerboard is made mainly from unbleached softwood kraft fibers which are relatively long in average fiber length and have reasonably good strength regenerative potentials. In contrast, the semichemical corrugating medium consists mainly of unbleached high-yield hardwood semichemical fibers which even in the virgin state will not make a high strength linerboard.

OCC can be separated by suitable means — e.g., Black-Clawson Cellusizer — into two fractions on the basis of fiber length in which the long fiber fraction will consist of mainly the long fibered softwood kraft fibers and the short fiber fraction mainly the short semichemical hardwood fiber and softwood fiber segments.

On the average, the long and short fiber fractions are in the ratio of 2:1 long fibers:short fibers. Thus the short fiber fraction must be used, otherwise fractionization is not economically practical.

Included in the short fraction will be 2-3% ray cells which contribute little, if any, to bonding and hence sheet strength. The ray cell fibers have a very significant adverse effect on drainage rate and the absorption of bonding agents. Previous studies carried out at The Institute of Paper Chemistry have shown that a significant improvement in strength can be obtained by removal of these fibers — i.e., materials passing 150-200 mesh screen. Removal can be accomplished by means of a Celleco Fractionator or other suitable separator. The effect of the removal of these fibers from the short fiber fraction will be established early in the study so that the information can be used in selecting the type of short fraction to be used in subsequent sections of this phase.

For a blend of 70:30 virgin pulp:OCC, the short fiber fraction in this blend will amount to approximately 10% of the total board furnish. The short fiber fraction will be expected to contain mainly high-yield hardwood semichemical fibers which have undergone very little delignification. Such fibers are difficult to bond, especially after recycling. Consequently, the objective of the work in this area is directed to the determination of how best to treat this short fiber fraction to optimize its contribution when used in the furnish of kraft linerboard. The approach to be used is set forth below.

2. Investigation of the Effect of Removing Fines from Short Fiber Fraction

3. Development of Short Fiber Fraction Base-line Data

The same general approach will be used in establishing a base line for the short fiber fraction as was used for the composite OCC as defined in Section III-C-1, pages 15-19.

a. Strength Development of Short Fiber Fraction

The short fiber fraction will be refined using the control sample refining conditions except that stock samples will be removed at various refining intervals for evaluation of stock characteristics and handsheets properties as in Part III-C-1, pages 15-19.

b. Blends of Virgin Pulp and Short Fiber Fraction

Because the freeness of the short fiber fraction will be markedly lower than the virgin pulp or long fiber fraction and the drainage resistance correspondingly higher, it is impractical to work with blends such as 70:30 virgin pulp:short fiber fraction. Therefore, the short fiber fraction blends will also include the proportions of long fraction which would be associated with the specified amount of short fiber fraction. The long fiber fraction will be prepared by the most appropriate conditions determined in IV-B-1, page 32.

(1) Refine each stock constituent separately and then combine to form primary and secondary stocks.

(2) Same as (1) above except refine short fiber fraction to its maximum bursting strength level.

c. Analysis of Results

Analysis of the results obtained above collated with the results obtained in III-C-1 and IV-B-1 should indicate the degree to which the short fiber fraction contributes to linerboard quality under different conditions of processing. These data will steer future research efforts in this area.

4. Optimization of Distribution of Short Fiber Fractions in Primary and Secondary Furnishes

a. Distribution Ratios

The planned distribution ratios are tabulated in Table III.

b. Evaluation: The stocks and handsheets will be evaluated for the properties listed in Part III-C-1, page 15.

c. Analysis of Results: These results should indicate the best way to distribute the short fiber fraction between primary and secondary furnishes for the conditions used.

5. Effect of Refining on Short Fiber Fraction

As mentioned the short fiber fraction will consist mainly of unbleached hardwood semichemical fibers and fragments of softwood kraft fibers. Unbleached semichemical fibers do not develop strength rapidly by refining nor can the strength level be developed to the level of a high strength sheet such as linerboard. Although the prospects of finding a marked increase in strength without an adverse effect on drainage is not great, it is desirable to carry out a

TABLE III

DISTRIBUTION OF FIBER

Type of Fiber, %					
Primary 70% of Board			Secondary 30% of Board		
	Fractionated OCC			Fractionated OCC	
Virgin Pulp, %	Long, %	Short, %	Virgin Pulp, %	Long, %	Short, %
Blend — 70% Pulp:30% Fractionated OCC					
40	20	10	30	0	0
45	16.6	8.3	25	3.3	1.7
49	14.0	7.0	21	6.0	3.0
55	10.0	5.0	15	10.0	5.0
60	6.7	3.3	10	13.3	6.7
65	3.3	1.7	5	16.6	8.3
Blend — 60% Pulp:40% Fractionated OCC					
30	26.7	13.3	30	0	0
40	20	10	20	6.7	3.3
50	13.3	6.7	10	13.3	6.7
60	6.7	3.3	0	20.0	10.0
Blend — 50% Pulp:50% Fractionated OCC					
20	33.3	16.7	30	0	0
25	30.0	15.0	25	3.3	1.7
35	23.3	11.7	15	10.0	5.0
50	13.3	6.7	0	20.0	10.0

limited exploration of the effect of refining variables on the papermaking potentials of the short fiber fraction. A 36-inch Bauer refiner will be used for this purpose. The procedure shown in Part III-D will be followed, see page 22.

6. Study of Chemical Treatments

It is proposed to investigate the effect of various chemical treatments as a means of improving the bonding capability of the short fiber fraction. The chemical treatments selected are designed to promote bonding by means of increased swelling and/or delignification of the hardwood semichemical fibers.

a. Swelling and Delignification Treatments

Because of the high temperature, pressure, fiber consistency and dispersing action attained in the Asplund mill when used to "de-asphalt" corrugated waste, the Asplund mill will be used in carrying out those chemical treatments where the Asplund conditions may be beneficial to the treatment. The treatments to be studied will be the same as in Part III-F-2, page 25, with the following additions:

(1) Combination of Sodium Sulfite and Carbonate at Elevated Temperature

Sodium sulfite and carbonate will be added to the stock in the Asplund mill so that the combination of temperature and chemicals will promote a degree of delignification and thereby hopefully improve their bonding. If this approach shows promise it may be possible to substitute green or white liquor.

(2) Jet Cooking With and Without Alkali

Increased bonding potential has been obtained by jet cooking groundwood in the presence of caustic soda. It is proposed that the short fraction be treated in a similar manner to determine if bonding can be improved. It is anticipated that it should be possible to process at approximately 5% consistency without modifying the present jet cooker.

(3) Delignification with Ethylene Glycol

This process is being tried as a relatively new approach to the pulping of various woods. It is suggested that it be investigated as a possible means of improving the quality of the short fraction. In practice it would need a chemical recovery system.

b. Investigation of Bonding Agents

A possible reason for the ineffectiveness of bonding agents on semichemical pulp is that the high-yield process does not delignify the fibers sufficient for the bonding agents to work successfully. Accordingly, the bonding agents will be tried before and after the short fiber fraction has been subjected to treatment with chemical swelling agents and delignification treatment described in (a) above. The same agents will be studied as were recommended in Part III-F.

7. Effect of Wet Pressing on Strength Development

It is believed that one of the primary reasons for the low strength of high-yield unbleached semichemical hardwood fibers which make up the corrugated medium is the low bonding strength. It has been found that better bonding and hence higher strength can be obtained by using high wet pressing. Accordingly, it is proposed to investigate the effect of wet pressing on strength development of the short fiber fraction.

V. FUNDED PULP TREATMENT STUDIES

Introduction

Recycled fibers generally show lower bonding potential than virgin fibers. The repulped fibers do not swell as readily in water and, hence, do not bond as well. Therefore, the objective of the research is to develop improved methods to increase the bonding potentials of recycled fiber without sacrificing productivity.

The strength of paper is dependent on at least four factors. These are (1) fiber strength, (2) the strength of the fiber-to-fiber bonds, (3) the number of bonds and (4) the distribution of bonds. These factors must be considered in research to improve the strength of recycled fibers without sacrificing productivity.

A number of techniques have been used to study the behavior of pulps in terms of the above factors. For example, gas adsorption or light scattering techniques are used to estimate bonded area. The zero span tensile test is often employed to measure fiber tensile strength. Various techniques are used to measure the wet fiber conformability and flexibility such as the hydrodynamic surface area and swollen specific volume which affect bonding.

In the case of chemical treatments such as ozonation, it is important to develop information on the changes in chemical composition of the fibers due to the treatment. Both the softwood kraft and hardwood semichemical fibers will be affected but to differing extents depending on the reactions involved and the reaction conditions.

As methods are studied to improve recycled fiber strength and drainage the above and other techniques will be used to determine the mechanisms of improvement and to guide the research efforts.

The lower bonding potentials of recycled fibers can be overcome, at least in part, by chemical treatments, additional refining, chemical bonding and production aids and by improved wet pressing.

Recent research on this project has shown that ozone treatments of OCC significantly increase most strength properties with little or no reduction in freeness. Thus ozonation treatments appear to have considerable promise. Accordingly, a major portion of the funded work in fiscal (IPC) 1979 will be concerned with use and application of the ozonation process. The specific objectives are:

1. Developing information on the best ozonation process conditions for OCC and suitable pilot or commercial scale processing equipment.

2. Determining the commerical feasibility of ozonation treatments by means of pilot scale machine trials.

3. Developing information on other chemical treatments to improve bonding.

In addition to the above, research of a more fundamental nature will be pursued to supplement planned FKBG work on the following areas:

1. Refining

2. Chemical additives

3. Wet pressing

4. Fractionation

A. Funded study of ozone treatment

Recent work indicates that ozonation of high yield pulp is one way to improve bonding. In veiw of its possible application to recycled fiber, work is in progress to determine if ozonation treatments are effective on recycled corrugated containers (DKLC or OCC) and their component fibers. This work is being carried out under Institute funding. The results obtained in preliminary trials have been encouraging and are briefly summarized below. A progress report on the findings is being prepared.

After making process improvements, a series of ozonation trials were carried out on recycled corrugated material using treatment times varying from 5 to 90 minutes. Three replicate trials were made at each treatment time. Ozone consumption levels ranged from about 0.8% O_3 on ovendry (o.d.) fiber at 5 minutes to about 12% O_3 at 90 minutes. The results are briefly summarized below.

1. At ozone consumption levels of about 2.3% or more, large increases were obtained in most handsheet properties which are highly dependent on fiber-to-fiber bonding. For example, at 2.3% O_3 consumption, burst and tensile increased about 35 and 27%, respectively. Much larger percentage increases were generally obtained as the O_3 consumption increased.

2. Modified ring compression increased with increasing O_3 consumption but at a slower rate than burst and tensile.

3. Tearing strength decreased with increasing O_3 consumption, but the average loss was relatively small (-2.9%) at 2.3% O_3 consumption.

4. The freeness decreases at the lower O_3 consumptions near 2.3% O_3 were small and possibly not significant. Thus, ozonation tends to produce significant changes in pulp properties without much effect on freeness.

5. Photomicrographs show that ozonation "erodes" the surface of the fiber and increases the conformability and, hence, bonding of the fiber when it is made into the sheet.

6. Preliminary cost estimates indicate that ozonation operating costs to achieve a 35% burst improvement would be about $12.5 per ton of fiber without considering possible savings in refining. The latter savings might amount to $2-$3 per ton.

7. Thus, it appears that ozone treatments can significantly increase most strength properties of recycled corrugated without any major reduction in freeness. The process should present no pollution problems and should have no detrimental effect on the white water system.

Based on the above, it is proposed to pursue funded research directed to determining the commercial feasibility of ozonation treatments of recycled corrugated containers. The following research is planned:

1. Legal and Patents

A limited search indicates that a number of patents have been issued which primarily cover the bleaching of various pulps with ozone alone or in combination with other chemicals. There appear to be no domestic patents which cover ozonation treatments of recycled fiber with the objective of enhancing the fiber bonding potentials.

It is proposed that a patent search be carried out to identify and review prior art relevant to the ozonation treatment of recycled fiber and pulp to increase strength and drainage. If original claims can be identified, protection in the form of patent rights should be purused to protect IPC and FKBG.

2. Process Research

Several subjects requiring analytical or empirical research have been identified. These subjects need to be addressed before a suitable understanding of the process can be attained although not necessarily in the order of presentation. It is not necessarily required that these research subjects be completed before pilot or commercial trials, however, it is advisable to have a better knowledge of the process to aid in pilot and/or commercial process trials and development.

a. Analysis of physico-chemical changes in fiber

In the work carried out to date, it appears that the fiber constituents of repulped corrugated containers react at different rates during ozonation treatments. Based on examination of stained fibers it appears that the springwood softwood fibers and hardwood vessel elements react first, followed by the hardwood fibers. The summerwood softwood fibers appear to be more resistant to ozone reactions. SEM micrographs of the fiber surface show that the ozonated fibers exhibit more fibril surface detail and surface "erosion" than the untreated fibers. Sheets formed from ozonated fibers appear to exhibit increased fiber-to-fiber contact and conformability than untreated fibers. In brief, ozonated fibers appear more conformable thus providing more and stronger bonded area when formed into sheets.

The literature suggests that the strength improvements obtained as a result of ozonation are a result of the hydrophilization of the lignin and modification of the fiber surface. It has been found that ozonation introduces carbonyl and/or carboxyl groups in pulp.

Because of the heterogeneous fiber mixture in OCC, it is proposed to carry out a limited study of the effects of ozonation on the changes in chemical composition of the softwood (liner fraction and/or virgin pulp) and hardwood fiber components. In addition, because the ozone is believed to react with the lignin in the fiber, the nature and amount of any extractives in the wash water will be determined. This information is needed to assess whether any effluent treatment problems might arise from the ozonation treatments.

b. Effect of ozonation process variables

The initial experimentation has established that ozonation treatments of recycled corrugated fiber effect substantial strength improvements in most strength properties with little or no loss in freeness. However, there has been insufficient time to determine the effect of a number of variables which may affect the treatment efficiency and physical characteristics of the treated stock. In order to guide the development of the process and the selection of suitable process equipment and parameters in pilot scale trials, it is proposed to develop information on variables such as the following:

1) Type of feed gas: O_3 generated from O_2 vs. O_3 generated from air.

2) Optimum degree of fluffing and consistency for various furnishes, e.g., DKLC, OCC, long and short fiber fractions, virgin pulp, etc.

3) Effect of reaction temperature.

4) pH effects during reaction.

5) Most suitable post-treatment washing and neutralization techniques.

6) Study of means to improve reaction performance at lower O_3 consumption levels.

7) Effect of ozone treatment on subsequent repulping.

8) Effect of contaminants and/or commercially processed recycled OCC.

c. Low (1-3%) consistency vs. high (30-45%) consistency ozonation treatment.

There is some evidence in the literature that ozonation treatments can be carried out at low consistencies rather than at the high consistencies normally employed. If effective on recycled fiber, low consistency treatments may have advantages. A limited amount of work is proposed to explore the possible advantages of the low consistency type treatment.

d. Development of prototype process equipment

The laboratory type equipment and procedures used to dewater and fluff the stock in the initial work may not simulate the stock characteristics which would be obtained with commercial equipment used for these purposes. Similarly, the reaction vessel used in the laboratory experiments has some serious drawbacks even for laboratory scale experiments and a different design would be required for commercial use. Therefore, concurrent with the research in other phases, it is planned to develop laboratory scale equipment which would be functionally similar to equipment required in pilot or commercial scale trials. The development work, carried out in cooperation with equipment suppliers, would involve the following:

1) Determination of the suitability of commercial fluffing equipment.

2) Development of improved laboratory scale fluffing equipment and procedures.

3) Development of suitable prototype ozonation reactor system.

3. Optimization of Ozonated and Untreated Fiber Combinations

There are a number of ways in which the untreated and ozonated fiber components of linerboard may be combined. For example, several alternatives are noted below.

-- Ozonated OCC combined with untreated virgin primary stock

-- Ozonated virgin kraft combined with untreated OCC

-- Ozonated virgin kraft plus long fiber fraction of OCC combined with untreated short fiber fraction

-- Ozonated long fiber fraction combined with untreated virgin and short fiber fraction

-- Ozonated short fiber fraction combined with untreated long fiber fraction and virgin kraft

Another variable which will affect performance of the various furnish combinations is the degree and type of refining, either before or after treatment. Considerable experimentation will be required to determine the most appropriate way to ozonate, refine and combine the various fiber components. The variables to be considered include:

a. Ozonation level

b. Amount of OCC or ozonated stock

c. Degree of refining of the separate components

4. Pilot Scale Process Trials

The proposed pilot development has as its general objective the determination of process characteristics and the hardware and manufacturing requirements required for its successful implementation. There are many identified problems outlined in the research plan. However, it is probable that others have not been recognized at this time. In general, this work will serve to experimentally verify the ideas and knowledge developed in other parts of the proposed work on ozonation treatments.

The pilot development phase of this work will address the following problems.

a. Selection of suitable pilot dewatering and fluffing equipment.

b. Specification and design of pilot ozone reaction equipment.

c. Specification of ozone generator requirements and best feed gas (O_2 vs. air).

d. Post-treatment washing.

e. Incorporation of ozonated stock into papermaking process.

f. Pilot scale trials.

5. Process Alternatives and Cost

Preliminary cost estimates indicate that the operating and capital requirements of ozonation treatments are favorably low compared to the basis weight increases required to achieve equivalent strength properties. The estimates of process and capital costs will be continually revised during the course of the planned research. When the pilot scale trials are completed, final cost estimates should be available to assess the potential savings which may be effected by the ozonation process.

B. Study of fiber treatments

Research of a more fundamental nature will be pursued in the following areas to supplement planned FKBG work:

1. Study of alternative chemical treatments for improving the strength of long and/or short fiber OCC fractions

Selected treatments will be given a preliminary screening to determine their effect on strength in relation to cost and to compare with ozonation treatments. The more promising treatments will then be studied to determine the most appropriate treatment conditions, the mechanism of improvement and cost effectiveness. The following treatments may be considered:

1. Asplund or jet cooking with alkali
2. Sodium sulfite/carbonate Asplund treatment
3. Hypochlorite or chlorine

2. Optimized use of chemical additives

The addition of chemical additives frequently improves strength levels at higher production rates than may be achieved by refining alone. The strength improvements may involve several factors as mentioned in the Introduction. The degree to which polymeric additives with ionic charges affect drainage depends on the structure of the polymer and the stock system environment. Since many factors influence the results obtained, this work will be directed toward optimizing strength and drainage by taking into account the fundamental mechanisms which may be involves.

Among the factors to be considered are:

1. Type and amount of polymer
2. Order of addition
3. Time
4. Ionic environment and pH
5. Kinetics of sorption
6. "Fines"
7. Type of furnish

Results will be interpreted in terms of the effect of the above on bonded area, bond strength and fiber strength.

3. Study of Refining Techniques

As fibers are refined they swell and the surface area increases due to loosening of the fibrillar structure. These factors increase the fiber bonding potential. To accomplish this, a considerable amount of energy is required. Most of the energy supplied by the shaft is converted into heat. Neglecting the pressure and velocity changes, the net refining energy (see eq. 1 below) is a measure of the energy transferred to the pulp.

$$E_t = E_n + E_i \tag{1}$$

where E_t = total energy, hp days/ton

E_n = net refining energy, hp day/ton

E_i = idling loss under no load, hp day/ton

In general, the net refining energy is assumed to depend on the number and severity of impacts on a fiber. Various approaches to defining the dependence of these factors on refiner plate design, operating conditions, etc., are discussed in the literature.

It appears that the change in a given property for a given pulp may be expressed as a function of net refining energy (E_n) and number of impacts (N). If such relationships are developed for any two properties -- e.g., edgewise compression and drainage resistance -- it is possible to develop a relationship between the two properties in terms of N (or E_n). Thus it should be possible to maximize a given property at a given drainage resistance by selection of N. Also, such relationships can be used in conjunction with eq. 1 to minimize the total energy required to obtain a given property.

It is proposed to investigate application of the above approaches to optimizing refining techniques for OCC and blends of OCC and virgin fiber.

4. Wet pressing

The purpose of this work is to determine the degree to which strength and water removal can be developed by increased wet pressing.

It is proposed to investigate the compaction characteristics of OCC sheets at press moisture levels in relation to sheet properties. The IPC dynamic compression apparatus will be used. This apparatus is capable of providing information on applied pressure and sheet caliper as function of time. Compression times of the order of 10 milliseconds can be obtained.

5. Fiber fractionation

a. Separation methods: The literature suggests that fractionation by type (i.e., liner and medium) rather than "fiber length" should give a long fiber fraction with superior properties. Separation by type based on the dispersability of the liner and medium fibers has not been commercially successful; however, other methods based on flotation processes may have merit for this type of separation. Exploratory research is proposed to determine the advantages of fractionation by type as compared to separation by length and to study the feasibility of other approaches to fractionation.

b. Optimization of pressure screen fractionation

The literature indicates that the strength and drainage characteristics of fractionated stock can be varied over a fairly wide range depending on the fractionation variables. In an effort to improve the efficiency of fractionation it is proposed to develop a model for the fractionator process taking into account such variables as flow rate, consistency, pressure drop, foil velocity and gap, screen size, stock freeness, etc.

Verification of the model should be carried out in pilot scale trials.

Based on the model it should be possible to better optimize fractionator operation to improve process control and obtain long-fiber fractions with improved strength and drainage characteristics.

VI. INVESTIGATION OF THE EFFECT OF ASPHALT DISPERSION PROCESS ON FIBER AND SHEET PROPERTIES

A. Background

One of the major problems associated with the manufacture of linerboard in part or whole with a recycled OCC furnish is the presence of a wide array of contaminants in the OCC. Technology and equipment are available for the practical removal of those contaminants whose density is significantly different from the papermaking fibers. The most troublesome contaminants are the plastic and other thermoplastic materials such as asphalt, wax, polyethylene (and propylene), polystyrene, pressure sensitive tape adhesive and hot melt adhesives.

The contaminants affect the production of linerboard in many ways. They adversely affect the appearance of the sheet, and cause difficulty in the forming, pressing and drying due to plugged wires and felts, "coated" press rolls and drier drums which reduce the efficiency of these operations. In addition they can have an adverse effect on the quality of the resulting linerboard in terms of lower strength and/or convertibility.

One of the most successful means of coping with thermoplastic contaminants such as asphalt, wax, etc., is the de-asphalting process employing an Asplund Defibrator (or suitable dispersing unit) developed at The Institute of Paper Chemistry for the Fibre Conservation Corporation (formerly Jute Research Group).

The de-asphalting process is very effective in "removing" or rendering innocuous such materials as wax, asphalt, and similar type contaminants. It is less effective on hot-melt adhesives and pressure sensitive adhesives. This process was widely used by the combination linerboard and boxboard mills in the 1950's as a means of eliminating asphalt and wax spots.

In recent years this approach has become a controversial issue. Some mills feel that the de-asphalting process is a very necessary operation in their production system. A few mills consider that the de-asphalting process adversely affects strength — e.g., bursting strength — requires too much energy, and the amount of asphalt in OCC is now relatively low, and the process is too ineffective in handling hot-melt adhesives and pressure sensitive adhesive to warrant its use.

Inasmuch as many mills (especially those using a high percentage of OCC in their furnish) consider the de-asphalting process essential in their paperboard making process and the conditions (elevated temperature, pressure, consistency, dispersion, etc.) may be utilized in promoting chemical treatment which enhances sheet strength, it is proposed to determine if the de-asphalting process adversely affects the properties of the resulting sheet.

B. Effect of Asplund Defibrator Conditions on Strength and Drainage of Composite OCC Fiber

1. Effect of Steam Pressure in Preheater and Defibrator

It is anticipated that the temperature conditions encountered in the Asplund processing of OCC recycled fibers may cause acid hydrolysis of the cellulose in the fibers. The higher the pressure the higher the temperature and consequently the greater the probability of acid hydrolysis which lowers the strength of the fibers. The following conditions will be studied.

a) 60 psi

b) 120 psi

c) 180 psi

2. Effect of Dwell Time in Preheater and Defibrator

The greater the dwell time the greater the probability of acid hydrolysis. The following times will be studied.

a) 5 Min in preheater and 1, 2, 5 min in defibrator

b) 10 Min in preheater and 1, 2, 5 min in defibrator

c) 20 Min in preheater and 1, 2, 5 min in defibrator

3. Effect of pH of Charged Stock

It is anticipated that the higher pH levels will eliminate or minimize acid hydrolysis. The following pH levels will be studied using caustic soda or alum.

a) 10.0

b) 9.0

c) 8.0

d) 5.0

4. Effect of Consistency

The purpose of this phase is to determine if loss in strength is associated with the cutting action which takes place in the defibrator chamber. The higher the consistency the greater the fluid shear and the lower the cutting. The following consistency levels will be studied.

a) 40%

b) 30%

c) 20%

d) 10%

C. Effect of Asplund Defibrator Conditions on Strength and Drainage of Long Fiber Fraction

1. Effect of Steam Pressure in Preheater and Defibrator — Same as Part B-1

2. Effect of Dwell Time in Preheater and Defibrator — Same as Part B-2

3. Effect of pH of Charged Stock — Same as Part B-3

4. Effect of Consistency — Same as Part B-4

D. Effect of Asplund Defibrator Conditions on Strength and Drainage of Short Fiber Fractions

1. Effect of Steam Pressure — Same as Part B-1

2. Effect of Dwell Time in Preheater and Defibrator — Same as Part B-2

3. Effect of pH of Charged Stock — Same as Part B-3

4. Effect of Consistency — Same as Part B-3

VII. SELECTION OF CANDIDATE APPROACHES

The data from Parts III to VI will be analyzed to determine the maximum use of OCC recycled fiber which can be used in the manufacture of kraft linerboard and meet the strength and drainage criteria, and the best candidate procedures. This will include the selection of candidate processes and treatment for machine trials.

VIII. MACHINE TRIALS

The objective of the research program outlined in Parts III through VII is twofold: (a) to optimize the use of OCC recycled fiber in the manufacture of competitive kraft linerboard and (b) the optimization must permit the production of linerboard at economically and functionally sound levels of strength without an adverse effect on drainage. The research program is to be pursued as a laboratory study of fiber furnishes in which the effects of various physical and chemical treatments on linerboard properties are to be measured in terms of duplex handsheets.

The laboratory research program will provide, among other things, information as to:

1. The maximum amount of OCC recycled fiber which can be used economically and functionally in the production of linerboard,
2. The most appropriate form (i.e., composite or fractionized OCC) in which to process and blend the OCC recycled fiber,
3. The most efficient distribution of the OCC recycled fiber in the primary and secondary furnishes, and
4. The most practical technology for developing the strength of the primary and secondary furnishes with no adverse effect on drainage.

The evaluation of the effects of different technology on sheet strength by means of handsheets permits the most economical and practical examination of a wide range of variables and degrees of treatment. However, such studies have limitations as to the scope of the information which can be developed and the degree to which it can be translated to mill scale processing without modification. For example, handsheets provide little if any information as to runnability on the paper machine — i.e., operational problems, speed limitation, forming, pressing and drying characteristics, etc., — or in the converting and fabrication operations. There are certain aspects of linerboard functionality such as scoring and folding performance which cannot be evaluated on a handsheet because these properties are functionally related to the directionality of the board as well as the strength of the fibers. Also, cost analysis and end use performance can only have real meaning if they are based on commercial scale production trials.

It is proposed that the translation of the laboratory results to mill scale trials be carried out by a two-step program involving first pilot scale trials and secondly mill scale trials. The pilot scale trials will involve stock preparation on pilot or small commercial size stock preparation equipment and the subsequent manufacture of the linerboard on a narrow width pilot paper machine capable of making "duplex" linerboard at reasonable speeds. The experimental linerboard can be converted into corrugated combined board on an experimental corrugator. This will provide material for evaluating the convertibility and the performance of the combined board and small size boxes.

The pilot scale trials will provide a means of making a preliminary evaluation of different technologies as well as work out problems which show up and which may require significant modification to the candidate process or technology. Pilot scale trials are far more amendable to working out change than are mill scale trials. Thus, the pilot scale trials will serve as a basis of selecting the technologies which appear to do the best job as well as fine "tune" the candidate "process" so that when they are used in mill trials they have a better chance to succeed.

The mill scale trials will provide linerboard in sufficient quantity, width and grade weights for conversion into corrugated combined board and boxes which can be subjected to a comprehensive analysis of performance in terms of a) convertibility, b) end-use performance, and c) overall comparative economics and acceptance.

PART IX PROJECT SCHEDULE SUMMARY SHEET

					1977		1978		1979		1980	
III--COMPOSITE RECYCLED FIBER FROM OCC												
IV--FRACTIONIZED OCC RECYCLED FIBER												
V--FUNDED PULP TREATMENT STUDIES												
VI--EFFECT OF THE ASPHALT DISPERSION PROCESS												
VII--SELECTION OF CANDIDATE APPROACHES												
VIII--MACHINE TRIALS												
PROGRESS REPORTING												
MANPOWER (MAN-YR)						1.3	1.1	1.1	1.1	1.1	1.0	0.4
CASH FLOW -- EQUIP. ($000)						15	15	5	5	5	10	--
-- TOTAL ($000)						80	70	60	60	60	60	20
CUMULATIVE TOTAL ($000)						80	150	210	270	330	390	410

DETAIL SHEET - PART III

INVESTIGATION OF ADDITIONS OF COMPOSITE CORRUGATED RECYCLED FIBER

					1977		1978		1979		1980	
CONTROL SAMPLE ANALYSIS												
DISTRIBUTION AND AMOUNT IN SHEET												
STUDY OF REFINING VARIABLES												
CHEMICAL ADDITIVES & TREATMENT												
WET PRESSING												
OVERALL ANALYSIS												
MANPOWER (MAN-HR)						0.5	0.4	0.4	0.3			
CASH FLOW -- EQUIP. ($000)						15	15	--	--			
-- TOTAL ($000)						25	15	20	15			
CUMULATIVE TOTAL ($000)						40	70	90	105			

DETAIL SHEET - PART IV

INVESTIGATION OF FRACTIONIZED OCC RECYCLED FIBER

					1977		1978		1979		1980	
FRACTIONATION OF OCC												
LONG FIBER FRACTION												
DEVT. OF BASELINE DATA												
OPTIMIZATION OF DISTRIBUTION												
REFINING OF LONG FRACTION												
STUDY OF CHEMICAL ADDITIVES												
WET PRESSING												
SHORT FIBER FRACTION												
REMOVAL OF FINES												
DEVT. OF BASELINE DATA												
OPTIMIZATION OF DISTRIBUTION												
REFINING OF SHORT FRACTION												
STUDY OF CHEMICAL TREATMENTS												
WET PRESSING												
MANPOWER (MAN-YR)								0.2	0.3	0.4		
CASH FLOW -- EQUIP. ($000)								--	--	--		
-- TOTAL ($000)								10	15	20		
CUMULATIVE TOTAL ($000)								10	25	45		

DETAIL SHEET - PART V
FUNDED PULP TREATMENT STUDIES

					1977		1978		1979		1980	
FUNDED STUDY OF OZONE TREATMENTS												
LEGAL AND PATENTS												
PROCESS RESEARCH												
OPTIMIZATION OF FURNISH COMBINATIONS												
PILOT SCALE PROCESS TRIALS												
PROCESS ALTERNATIVES AND COST												
FUNDED STUDY OF FIBER TREATMENT												
MANPOWER (MAN-YR)						0.8	0.7	0.5	0.6	0.5	0.5	
CASH FLOW -- EQUIP. ($000)						--	5	5	--	5	--	
-- TOTAL ($000)						40	40	30	30	30	25	
CUMULATIVE TOTAL ($000)						40	80	110	140	170	195	

DETAIL SHEET - PART VI

INVESTIGATION OF THE EFFECT OF THE ASPHALT DISPERSION PROCESS ON LINERBOARD

					1977		1978		1979		1980	
EFFECT OF ASPLUND CONDITIONS												
ON COMPOSITE OCC												
EFFECT OF ASPLUND CONDITIONS												
ON LONG FIBER												
EFFECT OF ASPLUND CONDITIONS												
ON SHORT FIBER												
MANPOWER										0.1	0.1	
CASH FLOW -- EQUIP. ($000)										--	--	
-- TOTAL ($000)										10	5	
CUMULATIVE TOTAL ($000)										10	15	

DETAIL SHEET - PARTS VII AND VIII
SELECTION OF CANDIDATE APPROACHES AND MACHINE TRIALS

					1977		1978		1979		1980	
ANALYSIS OF OVERALL OCC												
RESULTS												
SELECTION OF CANDIDATE												
APPROACHES												
PILOT MACHINE TRIALS												
MILL TRIALS												
MANPOWER (MAN-HR)											0.5	0.4
CASH FLOW -- EQUIP. ($000)											5	5
-- TOTAL ($000)											25	20
CUMULATIVE TOTAL ($000)											30	50